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BEARING-ONLY NAVIGATION FOR PROXIMITY OPERATIONS ON CIS-LUNAR NON-KEPLERIAN ORBITS

Abstract

The last decade is experiencing the consolidation of numerous Moon related space programs, declined into different science and exploration lunar missions targeted to the whole cislunar volume. Among those, the Artemis program plays a representative role, with its Lunar Orbital Platform-Gateway (LOP-G) to operate as long-term infrastructure on a Non-Rectilinear Halo Orbit. To accomplish many of its tasks, autonomous relative GNC capabilities for rendez-vous and docking operations on non-keplerian orbits shall be consolidated. Such techniques readiness increase would also open the door to a variety of missions entailing solving for relative dynamics in multi-gravitational environments.

The paper focuses on assessing the applicability of approaches, adopted in LEO scenarios to perform relative navigation between spacecraft flying on heterogeneous non-keplerian orbits. The so-called Bearing-Only technique is here selected as applicable, from a sensor suite perspective, on all spacecraft classes, from nano to large sats. Bearing-Only leans on the line-of-sight angular measurements only for state estimation. Although this technique requires simple and lightweight navigation sensors, its space applications have been sparsely studied because of inherent limitations in range estimation. Recent studies on LEO scenarios overcame the gap by performing specific sets of maneuvers to alter the natural evolution of the trajectory in favour of the observability.

Starting from the relative dynamics' formalisation, the paper exhaustively presents the promising results obtained by exploiting the Bearing-Only navigation technique to improve the relative state estimation whenever flying on non-keplerian orbits. A variety of different relative trajectories is analysed to highlight potential solutions that enhance the filter observability with minimum fuel consumption.

To allow for stricter navigational requirements, a specific guidance profile is computed from the minimisation of a convex cost function subject to non-linear constraints that enhance the relative trajectory observability. Additional equality and inequality constraints are included to account, for example, for maximum thrust thresholds and admissible chaser deviations from nominal orbit.

A Shrinking Horizon Model Predictive Control algorithm coupled with Extended Kalman Filter compose the proposed architecture. The optimisation problem is recursively solved along the maneuvering phase to update the manoeuvre plan and contain errors provoked by uncertain estimates. Validated high fidelity non-keplerian simulators have been adopted to perform a variety of numerical testing campaign and asses the architecture's robustness, showing the estimation errors can be reduced up to 0.05-0.1% of the relative distance.

The paper will critically discuss the adopted approach and the obtained results for practical applications.